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(54) **MICROFLUID DELIVERY DEVICE AND METHOD FOR MANUFACTURING THE SAME**

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
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USPC 347/20, 40–45, 47, 54–56, 59, 62–64
See application file for complete search history.

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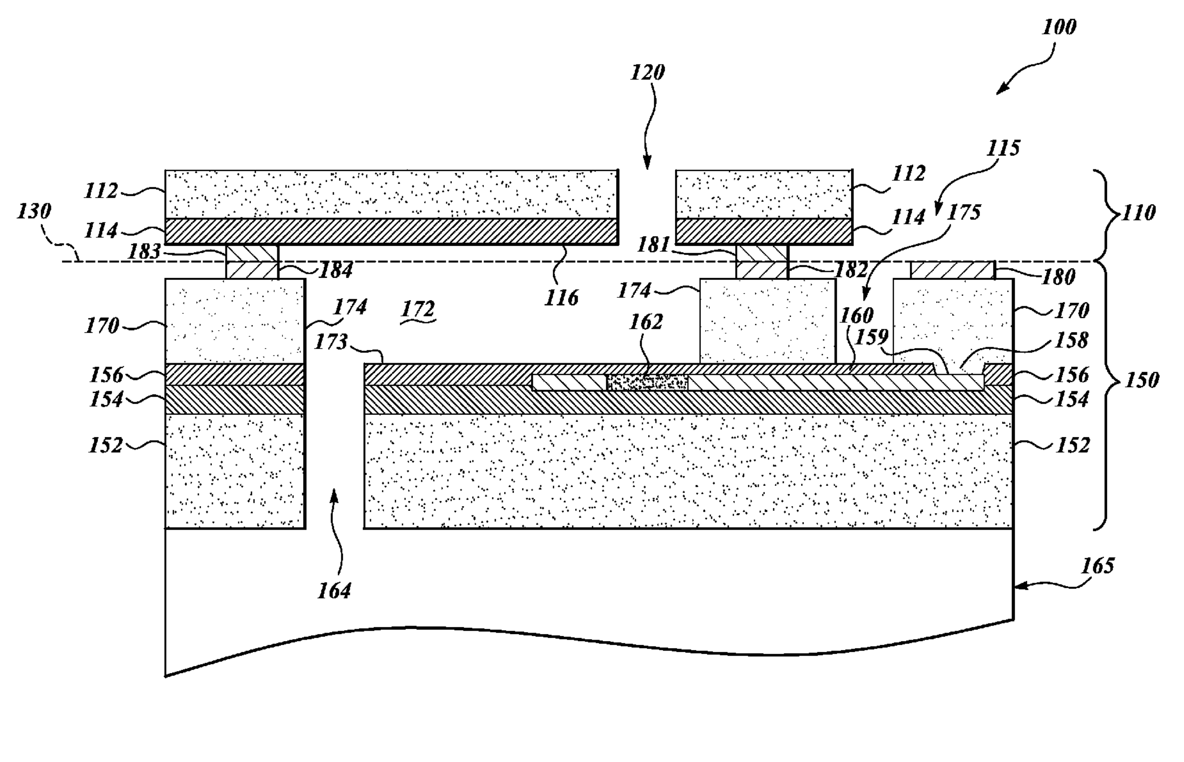
(57) **ABSTRACT**

Embodiments disclose herein are directed to a microfluidic delivery device that has a predominantly semiconductor structure, such as silicon. In particular, the structure for delivering fluid may be formed from polycrystalline silicon, also called polysilicon, or epitaxial silicon. The microfluidic delivery device that predominantly uses silicon based materials to form the structures that are in contact with the dispensed fluid results in a device that is compatible with a wide set of fluids and applications.

21 Claims, 5 Drawing Sheets



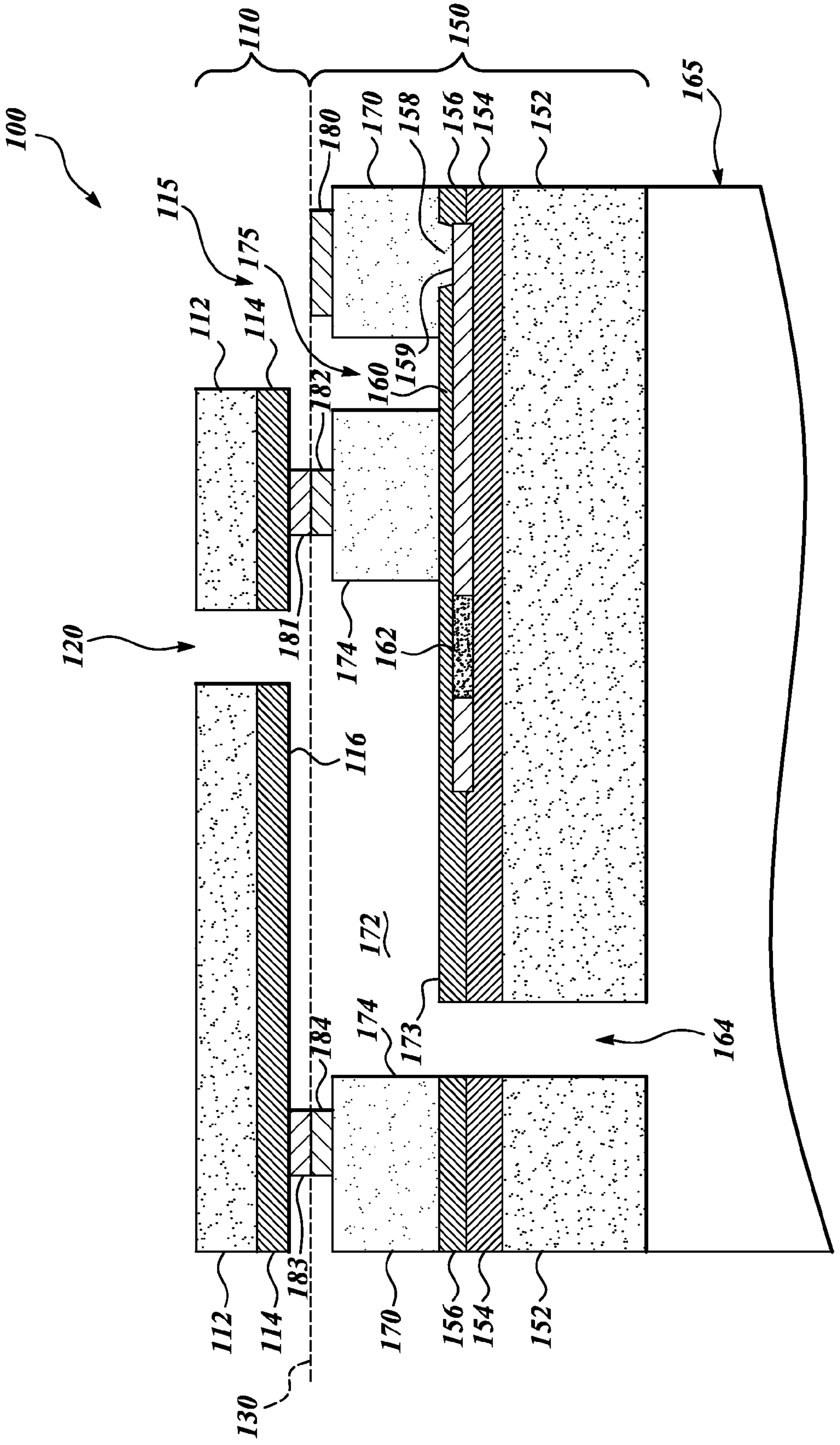

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Fig.1

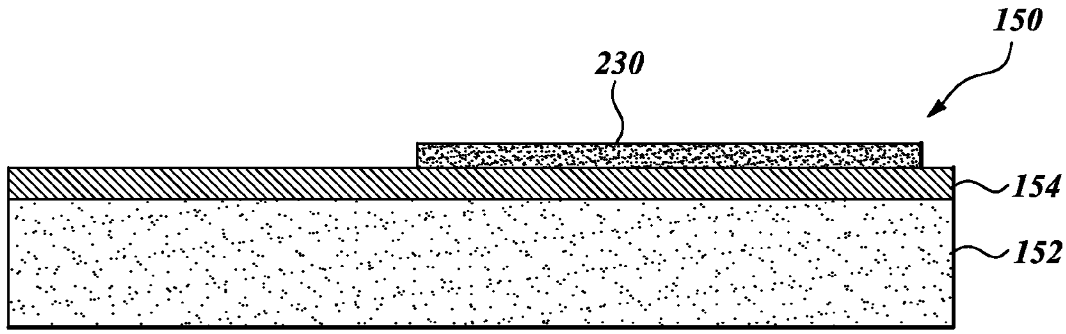


Fig.2A

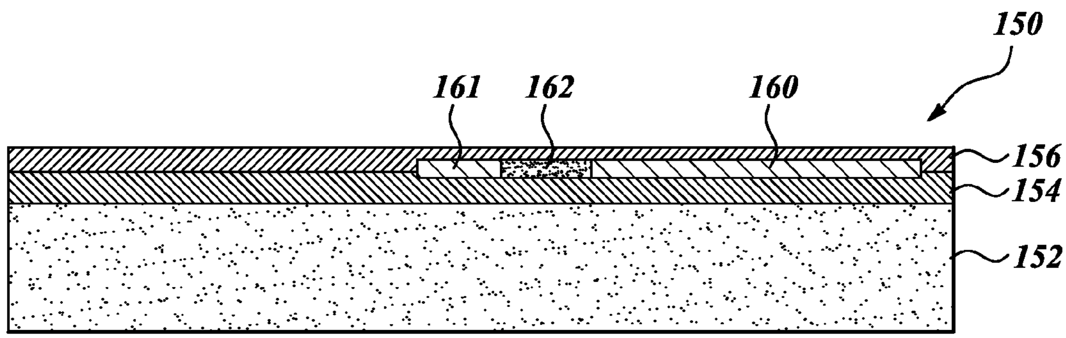


Fig.2B

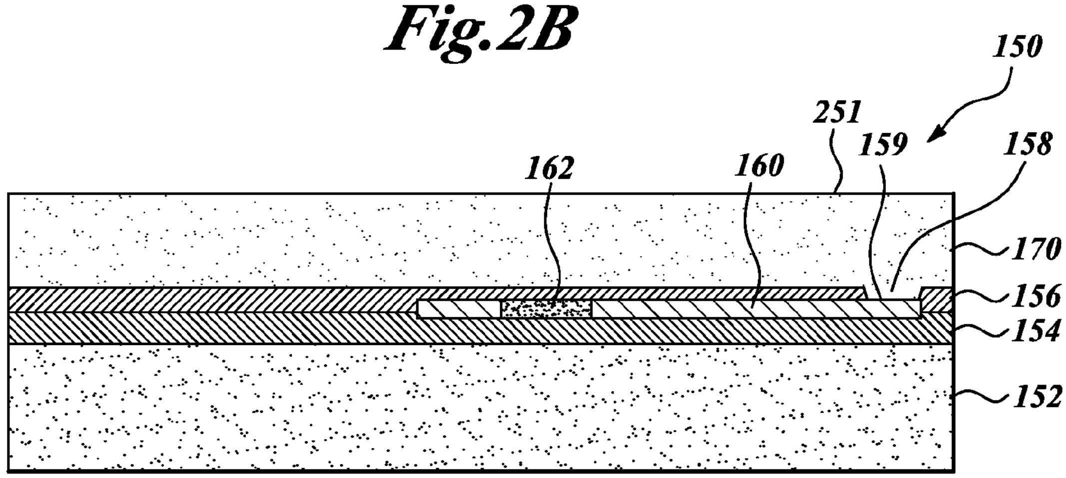


Fig.2C

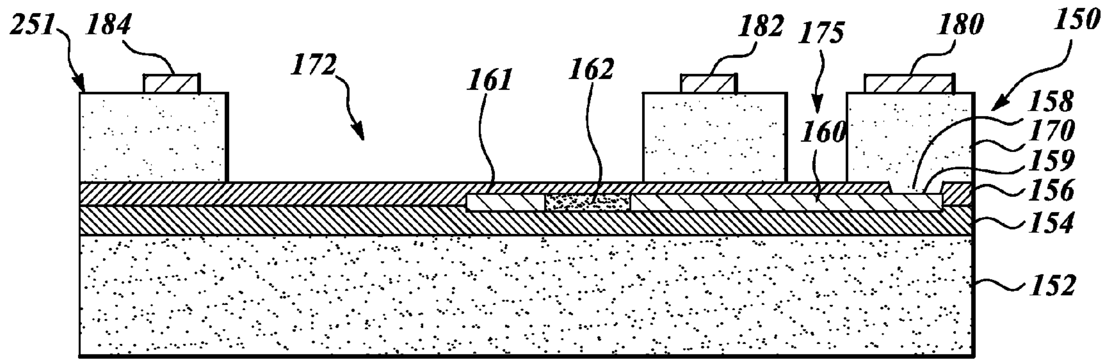


Fig.2D

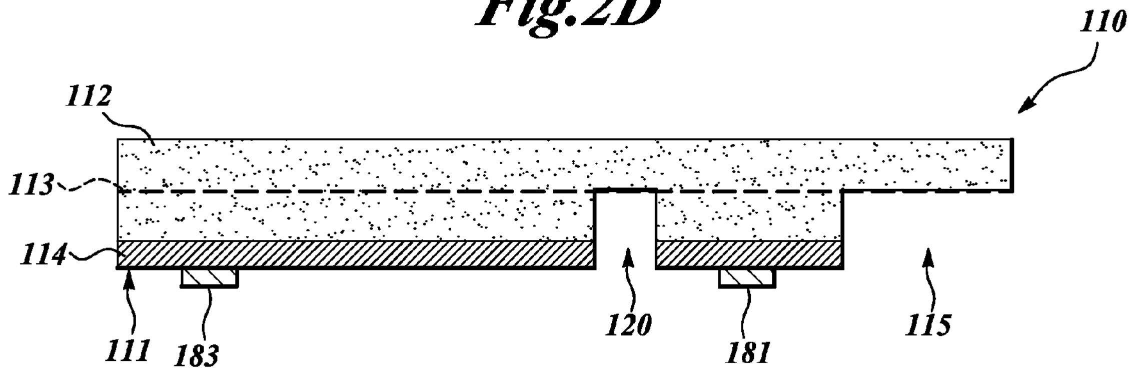


Fig.2E

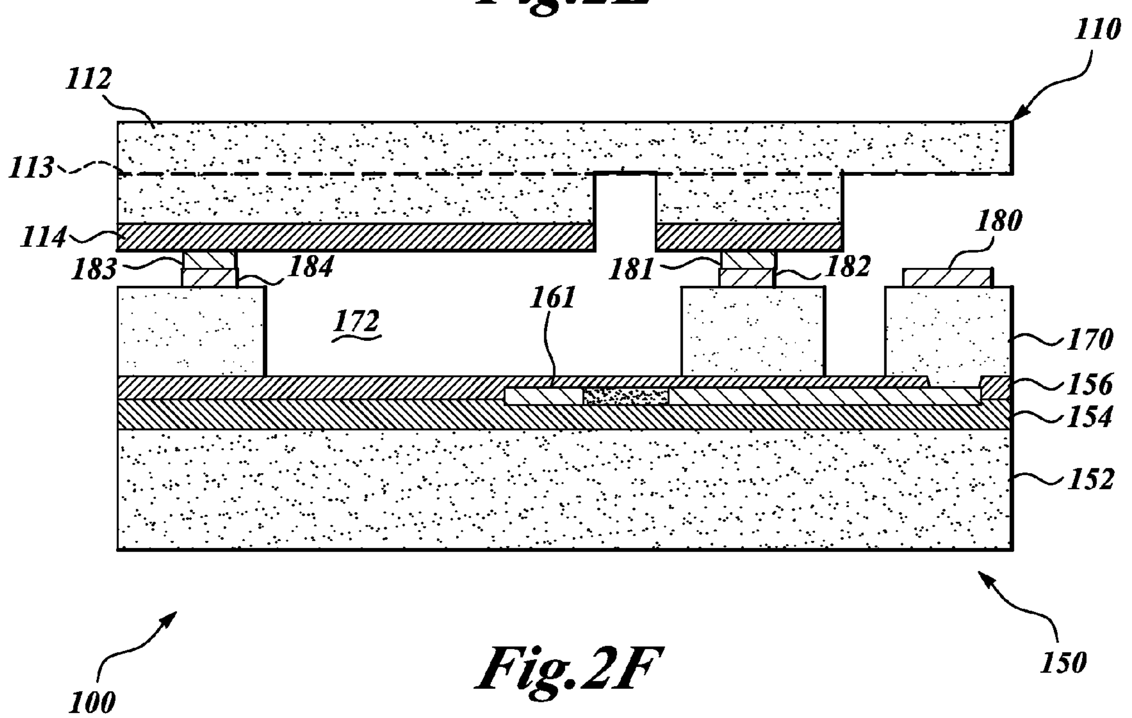


Fig.2F

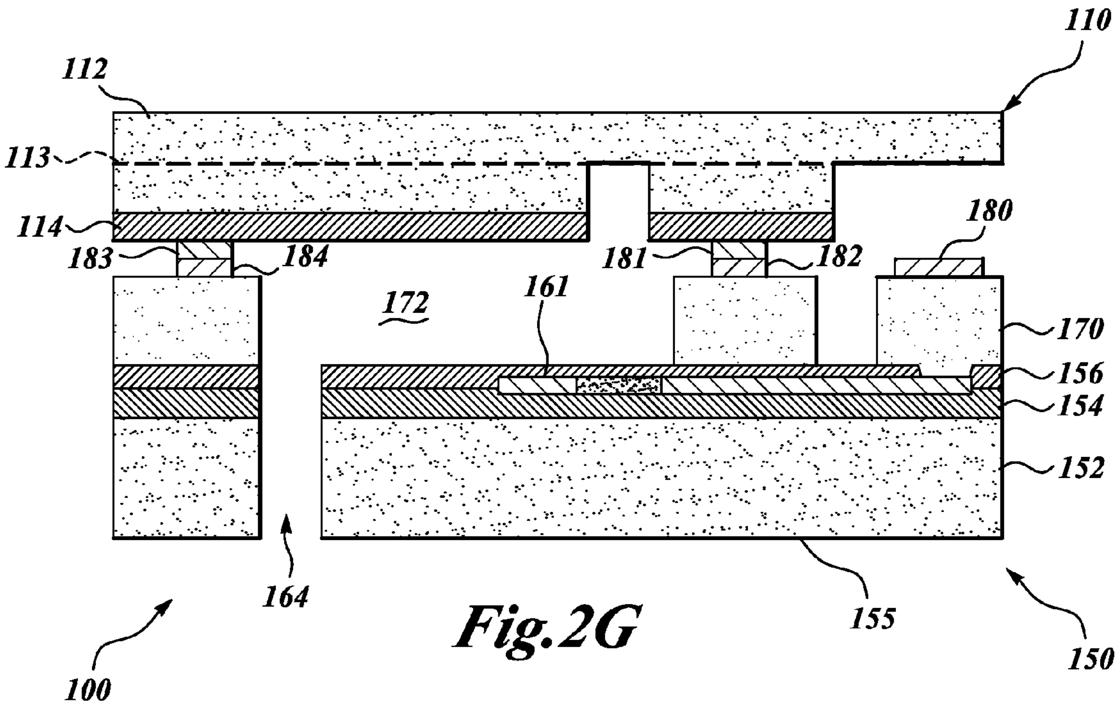
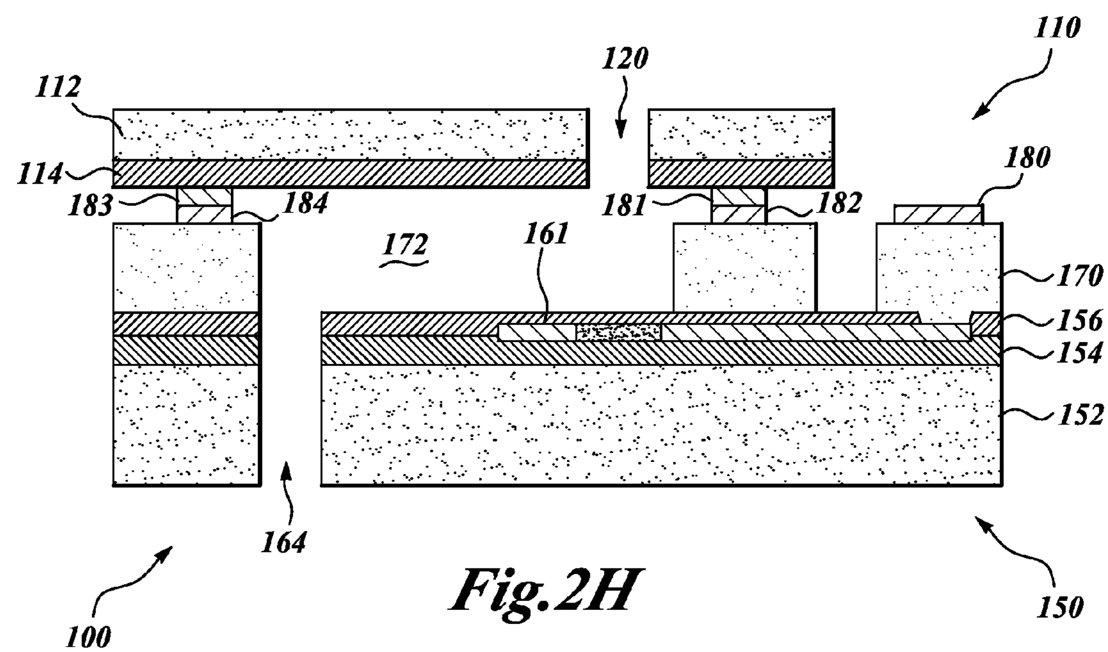

110
112
113
114
183
184
181
182
180
172
161
170
156
154
152
164
155
100
150

Fig.2G


110
120
112
114
183
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182
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172
161
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156
154
152
164
100
150

Fig.2H

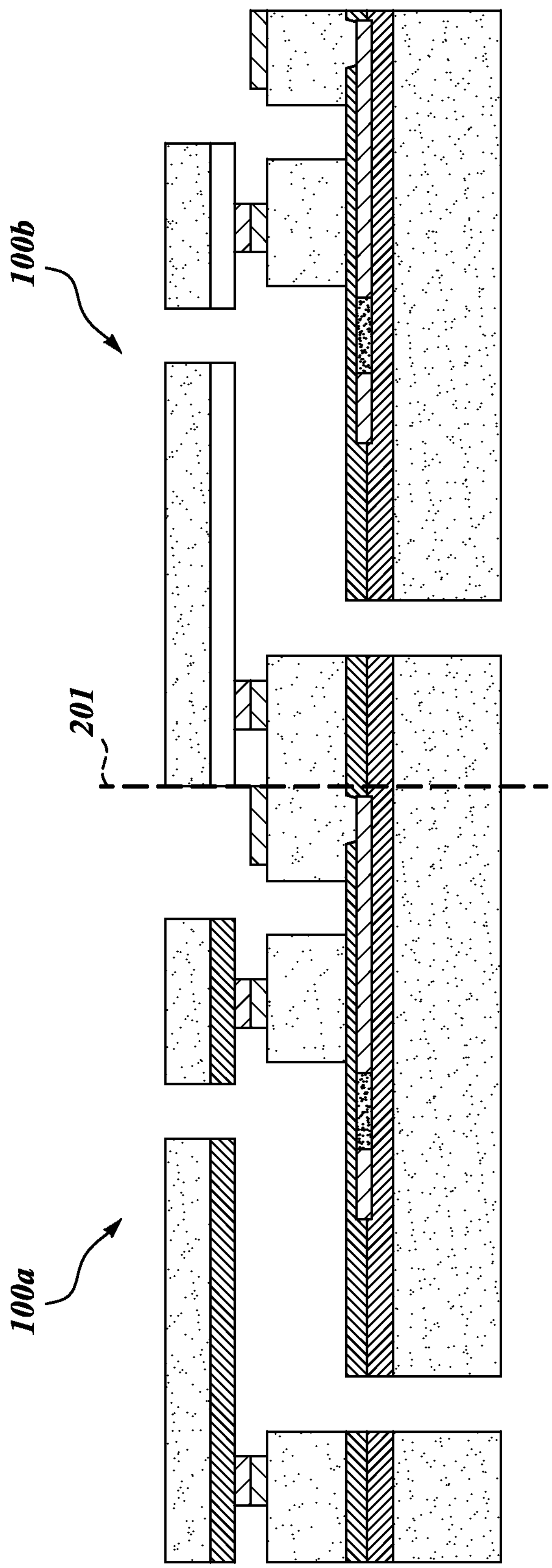

Fig. 2I

MICROFLUID DELIVERY DEVICE AND METHOD FOR MANUFACTURING THE SAME

BACKGROUND

1. Technical Field

Embodiments are directed to microfluidic delivery devices and methods of making the same.

2. Description of the Related Art

Microfluidic delivery devices are generally used in liquid dispensing applications, such as dispensing ink in ink-jet printers. A microfluidic delivery system can include fluid holding structures, such as a reservoir, and delivery structures, such as the microfluidic delivery device. Both the fluid holding structures and the delivery structures are in direct contact with the fluid for dispensing. These structures are typically made from organic materials, including polymers.

Many inks or other fluids are incompatible with these polymer materials. Using incompatible inks and other fluids, particularly organic fluids, in a polymer-based microfluidic delivery device can cause premature damage to, and can reduce the useful life of, such devices. For example, an organic fluid can etch the polymer structure and change the dimensions of the delivery device. This may cause the delivery device's efficiency and accuracy to degrade over time. In addition, the fluids may react with the polymer structure, weakening or otherwise damaging the structure. The fluid may also pick up contaminants from the polymer structure which may have undesirable effects on the fluid.

BRIEF SUMMARY

One or more embodiments disclose herein are directed to a microfluidic delivery device that includes structures that have compatibility with a wide group of fluids. In some embodiments, the microfluidic delivery devices are designed so that organic polymers do not come into contact with the dispensed fluids.

One embodiment is directed to a microfluidic delivery device that has a predominantly semiconductor structure, such as silicon. In particular, the structure for delivering fluid may be formed from polycrystalline silicon, also called polysilicon, or epitaxial silicon. The microfluidic delivery device that predominantly uses silicon based materials to form the structures that are in contact with the dispensed fluid results in a device that is compatible with a wide set of fluids and applications.

In one embodiment, the fluidic delivery device is constructed in first and second parts. The first part may include a fluid inlet, a heater, and a bottom and sidewalls of a fluid chamber. The first part may further include electrical contacts formed from poly tungsten silicide sandwiched between two layers of dielectric material. The heater, contacts, and dielectric material may be formed in or on a first semiconductor wafer base material, such as silicon.

In one embodiment, an epitaxial silicon layer may be grown atop the dielectric material. The fluid chamber is formed in the epitaxial silicon layer and the chamber inlet is formed in the silicon wafer using standard semiconductor processing techniques, including lithography and etching processes.

A second part of the fluidic delivery device may include a top of the fluid chamber and a nozzle that are formed in a second semiconductor wafer, such as silicon. The first and second parts are bonded together to form a stacked assembly that includes a plurality of fluidic delivery devices. The stacked assembly is then diced to form individual fluid delivery devices.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing and other features and advantages of the present disclosure will be more readily appreciated as the same become better understood from the following detailed description when taken in conjunction with the accompanying drawings.

FIG. **1** is a schematic cross section of a fluid chamber according to one embodiment of the present disclosure; and

FIGS. **2A-2I** are schematics of the fluid chamber of FIG. **1** at different stages in a manufacturing process according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

In the following description, certain specific details are set forth in order to provide a thorough understanding of various embodiments of the disclosure. However, one skilled in the art will understand that the disclosure may be practiced without these specific details. In other instances, well-known structures associated with electronic components, semiconductor fabrication, and MEMS fabrication have not been described in detail to avoid unnecessarily obscuring the descriptions of the embodiments of the present disclosure.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

As used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the content clearly dictates otherwise. It should also be noted that the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

In the drawings, identical reference numbers identify similar elements or acts. The size and relative positions of elements in the drawings are not necessarily drawn to scale.

Referring to FIG. **1**, a microfluidic delivery device **100** is illustrated. Generally described, the microfluidic delivery device **100** is configured to receive fluid from a fluid reservoir **165** and dispense or expel a small volume of the received fluid. Any fluid may be used in the microfluidic delivery device **100** including but not limited to ink, perfumes, medical fluids, and any other dispensable fluid. One use of such a delivery device is inkjet printer heads. Other potential uses include nebulizers for perfumes and for medical applications, such as an inhaler, and other liquid dispensing applications.

The microfluidic delivery device **100** includes a nozzle plate **110** and a chamber body **150**. The nozzle plate **110** includes a substrate layer **112**, which may be formed from a silicon wafer or glass, and a dielectric layer **114** which may be an oxide deposition, such as silicon oxide. The nozzle plate **110** also includes a nozzle **120** and pad access opening **115**, both formed as openings that extend through the nozzle plate **110**.

The chamber body **150** includes a silicon substrate **152**. First and second dielectric layers **154**, **156** are located on the silicon substrate **152**. The first and second dielectric layers **154**, **156** may include silicon oxide.

The chamber body **150** further includes a conductive interconnection component **160** that, in one embodiment, is a buried polysilicon runner. The conductive interconnect component **160**, that is coupled to a heater component **162**, that in one embodiment is a non-silicided polysilicon. The heater component **162** is disposed between the first dielectric layer **154** and the second dielectric layer **156** below the nozzle.

The second dielectric layer **156** has an opening **158** in at least one location to provide an electrical conduction path there through to the conductive interconnect component **160** and the heater component **162**. At the opening **158** is an electrical contact **159** to the conductive interconnect component **160**.

An epitaxial silicon growth layer **170** that formed on top of the second dielectric layer **156**. In that regard, a silicon on insulator (SOI) structure is formed. A fluid chamber **172** is located above the second dielectric layer **153** with sidewalls delimited by the epitaxial silicon growth layer **170**. Side surfaces **174** of the fluid chamber **172** are formed in the epitaxial silicon growth layer **170**.

A bottom surface of the chamber body **150** includes a fluid inlet **164** coupled to the reservoir **165**. The fluid inlet **164** is in fluid communication with the fluid chamber **172** and the fluid reservoir **165**. In that regard, the fluid inlet **164** places the reservoir **165** in fluid communication with the fluid chamber **172**.

The fluid inlet **164** is a through opening that extends through the silicon substrate layer **152** and the first and second dielectric layers **154**, **156**. The chamber body **150** may also include a trench **175** in the epitaxial layer **170**. The trench **175** may assist in electrically isolating the bonding pad **180** and the electrically conductive path through the epitaxial layer **170** and the interconnection component **160** to the heater component **162** from the structure surrounding the fluid chamber **172**.

On top of the epitaxial silicon growth layer **170**, are bonding rings **182**, **184** and bonding pad **180**. The bonding pad **180** is a conductive layer as is well known in the art. The bonding pad may be configured to receive a conductive wire for providing electrical coupling outside of the device **100**. The bonding pad **180** provides electrical communication to the heater component **162** through the epitaxial layer **170** and the interconnection component **160**.

The nozzle plate **110** and the chamber body **150** are bonded to each other by one or more bonding layers with a fluid tight seal. In particular, nozzle bonding rings **181**, **183** located on the dielectric layer **114** are bonded to chamber bonding rings **182**, **184** located on the epitaxial layer **170**. In some embodiments, the bonding rings **181**, **182**, **183**, **184** are gold layers, and the bond between the pads is created though a thermocompression process, discussed in more detail below.

The nozzle plate **110** forms an upper surface for the fluid chamber **172**. When the chamber body **150** and nozzle plate **110** are bonded together to form the microfluidic device **100**, the fluid chamber **172** is in fluid communication with an environment external to the device **100** through the nozzle **120** of the nozzle plate **110**.

As discussed above, the sidewalls of fluid chamber **172** are formed predominantly in the epitaxial layer **170**. The bottom surface **173** of the fluid chamber **172** is the top surface of the dielectric layer **156**. The fluid chamber sidewalls **174** may also comprise the bonding rings **181**, **182**, **183**, **184**. The top surface of the chamber **116** is the bottom surface of the dielectric layer **114** of the nozzle plate **110**. In one embodiment, the fluid chamber **172** has a depth of 10-50 microns from the top surface **116** to the bottom surface **173**.

Although the fluid chamber **172** is formed predominantly in the epitaxial layer **170**, it is to be appreciated that the fluid chamber may be formed in other types of semiconductor layers.

The heater component **162** is located adjacent the chamber bottom **173** below the nozzle **120** and is configured to heat the fluid within the fluid chamber **172**. By heating the fluid, the heater component **162** causes fluid in the fluid chamber **172** to be ejected through the nozzle **120** into the external environment. In particular, the heater component **162** vaporizes the fluid to create a bubble. The expansion that creates the bubble causes a droplet to form and eject from the nozzle **120**.

The size and location of heater component **162** can be selected based on desired performance properties of the device. In some embodiments, the heater component **162** is located at the bottom surface of the fluid chamber opposite and beneath the nozzle **120**. Specific details of the formation of the nozzle plate **110**, the chamber body **150** and their combination into the microfluidic device **100** will be discussed in more detail below.

As discussed above, one of the potential uses for the microfluidic device **100** is in medical applications. The fluids associated with medical applications are wide-ranging and include organic fluids, inorganic fluids, and various fluids that may have a diverse range of chemical and reactive properties. The materials used to form the microfluidic device **100**, and in particular the materials used to form the portions of the microfluidic device **100** that contact the fluid, do not contain organic polymers and are compatible with a wide set of fluids. For example, in some embodiments, the wafers or substrate layers **112**, **152** are made from silicon or glass, the dielectric layers **154**, **156**, **114** are silicon oxides, the rings **181**, **182**, **183**, **184** are gold, and the epitaxial layer **170** is epitaxial polysilicon. All of these materials are compatible with a wide range of fluids, including organic fluids.

FIGS. **2A-2I** illustrate stages of a process to form the microfluidic device in FIG. **1**, according to one embodiment of the present disclosure. The formation of the chamber body is detailed in FIGS. **2A-2D**, the formation of the nozzle plate is discussed with reference to FIG. **2D**, and the bonding of the nozzle plate and the chamber body to form a microfluidic device is discussed with reference to FIGS. **2F-2I**.

With reference to FIG. **2A**, a chamber body **150** is shown in an incomplete state. The chamber body includes a substrate layer **152**, which may be semiconductor material, such as silicon. The substrate layer **152** can also be doped with a desired conductivity type, either P-type or N-type. In one embodiment, the substrate layer **152** is approximately 700 microns thick.

A first dielectric layer **154** is formed on the substrate layer **152**. The first dielectric layer **154** may be formed using any deposition method. In one embodiment, the dielectric layer is formed using thermal oxidation and the dielectric layer comprises silicon oxide, such as dioxide. The first dielectric layer **154** may also be carbide or other inert dielectric material.

A first conductive layer **230** is deposited on a portion of the first dielectric layer **154**. The first conductive layer **230** may have a width that is approximately the same as the diameter of a nozzle, such as the nozzle **120** of FIG. **2**H, in one embodiment. The first conductive layer **230** may have a thickness between approximately 0.2 and 1 micron. In some embodiments, such as the embodiment shown in FIG. **2**A, the first conductive layer **230** has a thickness between 0.4 microns to 100 nm. The first conductive layer **230** can be formed using chemical vapor deposition. In some embodiments, the first conductive layer **230** is formed using low-pressure chemical vapor deposition. The first conductive layer **230** or a portion thereof forms the heater component **162**.

In one embodiment the first conductive layer **230** is polysilicon. Polysilicon has a relatively high sheet resistance, Rs, such that it resists the flow of electrical current as compared to a low sheet resistance material. In that regard, in one embodiment, the heater component **162** is polysilicon. When electrical current flows through the relatively high resistance of the polysilicon of the heater component **162**, heat is generated.

In some embodiments, it may be undesirable for the entire first conductive layer **230** to act as a heater. Therefore, a non-heater portion of the first conductive layer **230** is changed into a silicide via silicidation and forms the conductive interconnect component **160** for carrying electrical current to the heater component **162**. In that regard, the conductive interconnect component **160** has low resistivity, while the heating component **162** has high resistivity.

In one embodiment, the conductive interconnect component **160** are subject to silicidation, such as tungsten or titanium silicidation. In the embodiment shown in FIG. **2**B, the conductive interconnect component **160** is poly tungsten silicide.

In this way, the conductive interconnect component **160** facilitates electrical current flow from the bonding pad **180**, see FIG. **2**D, and through the heater component **162**.

A second dielectric layer **156** is formed over the first dielectric layer **154**, the heater component **162**, and the conductive interconnect component **160**, thereby insulating heater component **162** and the conductive interconnect component **160**. The second dielectric layer **156** may be formed using any deposition method. In one embodiment, the second dielectric layer **156** is formed using low-pressure chemical vapor deposition. The second dielectric layer **156** may also be carbide or other inert dielectric material.

Referring now to FIG. **2**C, an opening is formed through the second dielectric layer **156**, exposing the contact **159**. Various methods of forming the opening through the second dielectric layer **156** may be used include etching steps, which may include dry etching and/or wet etching or partial deposition of the second dielectric. In an alternative embodiment, the second dielectric layer **156** is deposited with the opening **158**.

An epitaxial silicon growth layer is formed over the second dielectric layer **156** and in contact with the contact **159**. The epitaxial silicon growth layer **170** of FIG. **2**C is a crystalline layer of silicon, for example polysilicon. The epitaxial silicon growth layer **170** may be 10 to 50 microns thick, preferably approximately 15 microns thick.

After the epitaxial silicon growth layer **170** is formed, it may be subjected to a planarization step. The planarization steps planarizes the upper surface **171** of the epitaxial silicon growth layer **170** forming a substantially flat plane. A planar upper surface **171** of the silicon growth layer **170** facilitates the bonding of the chamber body **150** with the nozzle plate; see, e.g., FIG. **2**F. Any known method of planarization of epitaxial silicon may be used. In one embodiment, a chemical-mechanical-polishing process, known as a CMP process, may be used to planarize the upper surface **171** of the epitaxial silicon growth layer **170** into a substantially flat plane. Using the CMP process, the upper surface **171** of the epitaxial silicon growth layer **170** is planarized by rotating the upper surface **171** of the epitaxial silicon growth layer **170**, and by extension, the whole chamber body **150**, under pressure against a polishing pad in the presence of a silica-based alkaline slurry.

With reference to FIG. **2**D, the bonding rings **182**, **184** and the electrical bonding pad **180** are formed on the upper surface **171** of the epitaxial silicon growth layer **170**. The bonding rings **182**, **184** and the bonding pad **180** may include a barrier layer, a seed layer, and a gold electroplated layer.

The nitrides of refractory metals, such as titanium, tantalum, and tungsten, may be used in the barrier layer to prevent diffusion between the epitaxial silicon growth layer **170** and the bonding rings **182**, **184** and the bonding pad **180** materials. The seed layer acts to provide a structure for the gold electroplating layer to seed or adhere on. The seed layer may be a mesh layer formed through electron-beam evaporation, low-pressure chemical vapor deposition, or other methods. After the seed layer is formed on the barrier layer, a gold layer may be electroplated onto the chamber body **150** to finalize the bonding rings **182**, **184** and the bonding pad **180**.

The fluid chamber **172** and a trench **175** are formed in the epitaxial silicon growth layer **170** by etching or other acceptable semiconductor processing techniques. Known etching techniques, including wet etching, dry etching, or a combination of wet and dry etching, are controllable and suitable for etching the fluid chamber **172**. The depth of the etching is through the entire depth of the epitaxial silicon growth layer **170**.

With reference to FIG. **2**E, the formation of the nozzle plate **110** is shown and discussed. As with the chamber body **150**, the nozzle plate **110** includes a substrate layer **112**. The substrate layer may be any substrate material, such as a semiconductor substrate or glass. In some embodiments, the substrate layer **112** is between approximately 100 and approximately 800 microns thick.

A dielectric layer **114** is formed on the substrate layer **112**. The dielectric layer **114** may be formed using any may be formed using any deposition method for forming oxidizing silicon substrates that results in a dielectric layer that is compatible with the fluids to be used in the microfluidic device. In this embodiment, the dielectric layer is formed using thermal oxidation and the dielectric layer comprises silicon dioxide. The dielectric layer **114** may also be carbide or other inert dielectric material.

The bonding rings **181**, **183** are formed on the lower surface **111** of the dielectric layer **114**. The bonding rings **182**, **184** are formed of a barrier layer, a seed layer, and an electroplated gold layer.

The nozzle **120** is formed through the dielectric layer **114** and at least partially though the substrate layer **112** by etching or other acceptable semiconductor processing technique. Known etching techniques, including wet etching, dry etching, or a combination of wet and dry etching, are controllable and suitable for etching the nozzle **120** in the dielectric layer **114** and the substrate layer **112**.

An area for accessing the pad **180** of the assembled microfluidic device **100**, see FIGS. **2**F-**2**H, may also be etched into the nozzle plate **110**. For example, pad access **115** is formed through the dielectric layer **114** and at least partially though the substrate layer **112** by wet and/or dry etching or other acceptable semiconductor processing techniques.

Optionally, the substrate layer **112** of the nozzle plate **110** may be a silicon on insulator-like wafer with a buried oxide layer **113**. The buried oxide layer **113** is surrounded on both sides by silicon layers. The silicon on insulator-like structure may provide for a more precise shaping of the nozzle. In an embodiment with the buried oxide layer **113**, the nozzle **120** may be formed through the dielectric layer **114** and at least partially though the substrate layer **112** to the buried oxide layer **113**.

Referring now to FIG. **2**F, the bonding of the nozzle plate **110** and chamber body **150** is depicted. The nozzle plate **110** and chamber body **150** are bonded through the nozzle plate **110** bonding rings **181**, **183** and respective chamber body **150** bonding rings **182**, **184**.

In embodiments with gold bonding rings **182**, **184**, **181**, **183**, the nozzle plate **110** and chamber body **150** may be bonded together using a thermal compression bonding method. In such a method, the nozzle plate **110** and chamber body **150** are compressed together under high heat to bond the respective gold bonding rings **182**, **184**, **181**, **183** together. Although gold bonding rings and thermal compression is the preferred method of bonding the nozzle plate **110** and chamber body **150** together, any other acceptable bonding structures and methods may be used.

With the nozzle plate **110** and chamber body **150** bonded together, the fluid chamber **172** is complete. The bottom of the fluid chamber **172** is bounded by the upper surface of the second dielectric layer **156**. The top of the fluid chamber **172** is bounded by the lower surface of the dielectric layer **114** of the nozzle plate **110**. The sides of the fluid chamber **172** are bounded by the epitaxial silicon growth layer **170** and the bonding rings **182**, **184**, **181**, **183**.

Referring now to FIG. **2**G, an embodiment of the fluid inlet formation and backside grinding of the microfluidic device **100** is shown. The backside **155** of the microfluidic device **100** is ground using a mechanical grinding process to achieve a uniform surface and to reduce the overall thickness of the microfluidic device **100**.

After grinding the backside **155**, the fluid inlet **164** may be formed. The fluid inlet **164** is formed through the substrate layer **152** and the first and second dielectric layers **154**, **156** to connect a fluid reservoir **165**, not shown, with the fluid chamber **172**. Known methods of forming the fluid inlet **164** through the substrate layer **152** and the first and second dielectric layers **154**, **156** include etching steps, such as dry etching or wet etching, wherein the pattern of the second dielectric layer **156** that is not etched is masked off and then the path to form the contact **159** is etched. In a preferred embodiment, the fluid inlet **164** is formed through the substrate layer **152** and the first and second dielectric layers **154**, **156** using a deep reactive-ion etching process. The deep reactive-ion etching process is well-suited for creating deep and high aspect ratio features in substrates, such as the formation of the fluid inlet **164**.

Referring now to FIG. **2**H, an embodiment for front side grinding and etching for the buried oxide layer of the microfluidic device **100** is shown. The starting thickness of the substrate layer **112** may be between 100 and 800 microns. In some embodiments, the substrate layer **112** thickness is reduced to between approximately 10 and approximately 100 microns.

In embodiments wherein the substrate layer **112** does not include the buried oxide layer **113**, then the substrate layer **112** may be ground using a mechanical grinding process to achieve a uniform surface and to reduce the overall thickness of the substrate layer **112** and, in turn, the microfluidic device **100**. The grinding of substrate layer **112** may be carried out until the nozzle **120** passes through the remaining thickness of the substrate layer **112** and connects the fluid chamber **172** in fluid communication with the external environment.

In embodiments wherein the substrate layer **112** includes the buried oxide layer **113**, the substrate layer **112** may be ground to the buried oxide layer **113** using a mechanical grinding process. After grinding the substrate layer **112** to the buried oxide layer, the buried oxide layer **113** may be removed through an etching process to open the outlet of the nozzle **120** such that the nozzle **120** connects the fluid chamber **172** in fluid communication with the external environment. Known etching techniques for etching the buried oxide layer **113**, include wet etching, dry etching, or a combination of wet and dry etching. In some embodiments, the buried oxide layer **113** may be blanket etched such that the entire buried oxide layer **113** is removed, or the buried oxide layer **113** may be masked such that only the buried oxide layer **113** at the nozzle **120** is etched.

With the opening of the nozzle **120** to connect the fluid chamber **172** to the external environment, the structure of the microfluidic device **100** is complete. The fluid inlet **164** connects a fluid reservoir to the fluid chamber **172** to provide a source of fluid to the microfluidic device **100**, the nozzle **120** connects the fluid chamber **172** to the outside environment, and the heater **162** produces the energy that forces the fluid from the fluid chamber **172**, through the nozzle **120**, and out into the external environment.

In some embodiments, the single microfluidic device **100** is just one of many microfluidic devices formed at a single time. A nozzle plate **110** may include numerous nozzles **120** and other structural elements in an array, while the chamber body **150** may include numerous fluid chambers **172**, heaters **162**, fluid inlets **164**, and other structural elements in a corresponding array. When bonded together, such a nozzle plate and chamber body may create a plurality of microfluidic devices **100**. For example, FIG. **2**I depicts two such microfluidic devices **100***a*, **100***b*, joined together in a single, repeating structure.

As shown in FIG. **2**I, the two microfluidic devices **100***a*, **100***b* may be separated, or diced, along the line **201**. The dicing process may include scribing and breaking, whereby the front or back side of the microfluidic devices **100***a*, **100***b* are scribed to create a weak line, and then a bending force causes the microfluidic devices to break and separate. The dicing process may also include mechanical sawing whereby a dicing saw is used to cut the microfluidic devices **100***a*, **100***b* along the line **201**, or may include laser cutting whereby a laser is used to separate the microfluidic devices **100***a*, **100***b* along the line **201** and into individual microfluidic devices **100***a*, **100***b*.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled.

The invention claimed is:

1. A microfluidic device comprising:

a nozzle plate including a dielectric layer, a substrate layer, and a nozzle;

a chamber body, the chamber body including a semiconductor substrate, a dielectric layer over the semiconductor substrate, and a semiconductor layer over the dielectric layer, the semiconductor layer being a layer of epitaxial polysilicon and the semiconductor substrate being a silicon substrate;

a chamber at least partially formed in the semiconductor layer and covered by the nozzle plate, the chamber in fluid communication with the nozzle; and

a fluid inlet comprising an aperture through the chamber body and in fluid communication with the chamber.

2. The microfluidic device of claim **1** wherein:

the chamber is formed by a top, a bottom, and sidewalls;

the top of the chamber is formed by a surface of the dielectric layer of nozzle plate, the bottom of the chamber is formed by a surface of the chamber dielectric layer; and

at least a portion of the sidewalls is formed by a portion of the semiconductor layer.

3. The microfluidic device of claim **1** wherein the dielectric layer of the nozzle plate and the dielectric layer of the chamber body include silicon dioxide.

4. The microfluidic device of claim **1** wherein the dielectric layer of the chamber body includes a lower dialectic layer and an upper dielectric layer, and a buried silicon runner therebetween, the buried silicon runner including a heating portion and an interconnection portion.

5. The microfluidic device of claim **4** wherein the heating portion is a polysilicon material and the interconnection portion is a silicide material.

6. The microfluidic device of claim **1**, further comprising:

a bonding pad;

a heater; and

a trench in the chamber body that electrically isolates the boding pad from the chamber body.

7. The microfluidic device of claim **6** wherein the nozzle plate includes a pad access structure above the electrical bonding pad.

8. The microfluidic device of claim **1** further comprising:

a chamber body bonding ring formed on an upper surface of the semiconductor layer of the chamber body; and

a nozzle plate bonding ring formed on a lower surface of the dielectric layer of the nozzle plate, the chamber body bonding ring bonded to the nozzle plate bonding ring.

9. A microfluidic device comprising:

a nozzle plate including a dielectric layer, a substrate layer, and a nozzle, the dielectric layer located on a surface of the substrate layer;

a chamber body including a silicon substrate, a dielectric layer over the silicon substrate, and a silicon layer over the dielectric layer, the chamber body including an opening in the silicon layer, wherein the chamber body is coupled to the nozzle plate;

a chamber defined by the opening in the chamber body and the nozzle plate, the chamber being configured to hold a fluid; and

a fluid inlet delimited by an opening through the chamber body, the nozzle being in fluid communication with the fluid inlet through the chamber.

10. The microfluidic device of claim **9**, further comprising a heater component in the chamber body, the heater component configured to heat the fluid in the chamber to expel fluid through the nozzle.

11. The microfluidic device of claim **10**, wherein the heater component is facing the nozzle.

12. The microfluidic device of claim **9**, wherein the chamber body is coupled to the nozzle plate by metallic bonding pads.

13. A microfluidic device comprising:

a fluid reservoir having an interior configured to contain fluid; and

a microfluidic delivery device mechanically coupled to the fluid reservoir and including:

a nozzle plate including a nozzle having an opening extending through the nozzle plate;

a chamber body coupled to the nozzle plate, the chamber body including a semiconductor substrate, a dielectric layer over the semiconductor substrate, and an epitaxial silicon growth layer over the dielectric layer;

a chamber at least partially formed by a cavity formed in the epitaxial silicon growth layer and a surface of the nozzle plate, the chamber in fluid communication with the nozzle and in fluid communication with the fluid reservoir; and

a metal layer forming a ring around the fluid chamber and a fluid tight seal between the chamber body and the nozzle plate, the metal layer coupling the chamber body to the nozzle plate.

14. The microfluidic device of claim **13** wherein:

the chamber includes a top, a bottom, and sidewalls;

the chamber top is the surface of the nozzle plate, the bottom of the chamber is a surface of the dielectric layer of the chamber body; and

at least a portion of the epitaxial forming at least a portion of the sidewalls.

15. The microfluidic device of claim **14**, further comprising:

a bonding pad;

a heater; and

a trench in the chamber body that electrically isolates the boding pad from the portion of the sidewalls formed by the portion of the epitaxial forming at least the portion of the sidewalls.

16. The microfluidic device of claim **13**, further comprising a heater component in the chamber body, the heater component configured to heat the fluid in the chamber to expel fluid through the nozzle.

17. The microfluidic device of claim **16**, wherein the heater component is facing the nozzle.

18. The microfluidic device of claim **13** wherein the metal layer is gold.

19. A microfluidic device comprising:

a nozzle plate including a dielectric layer, a substrate layer, and a nozzle;

a chamber body, the chamber body including a semiconductor substrate, a dielectric layer over the semiconductor substrate, and a semiconductor layer over the dielectric layer;

a chamber at least partially formed in the semiconductor layer and covered by the nozzle plate, the chamber in fluid communication with the nozzle;

a fluid inlet comprising an aperture through the chamber body and in fluid communication with the chamber; and

a chamber body bonding ring formed on an upper surface of the semiconductor layer of the chamber body and a nozzle plate bonding ring formed on a lower surface of the dielectric layer of the nozzle plate, the chamber body bonding ring bonded to the nozzle plate bonding ring.

20. The microfluidic device of claim **19** wherein:

the chamber is formed by a top, a bottom, and sidewalls, the top of the chamber is formed by a surface of the dielectric layer of the nozzle plate, the bottom of the chamber is formed by a surface of the dielectric layer of the chamber body; and

at least a portion of the sidewalls include a portion of the semiconductor layer.

21. The microfluidic device of claim **19** wherein the dielectric layers of the nozzle plate and the chamber body includes silicon dioxide.

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